THE WILSON BULLETIN

A QUARTERLY MAGAZINE OF ORNITHOLOGY

Published by the Wilson Ornithological Society

VOL. 106, NO. 3 | SEPTEMBER 1994 | PAGES 421–584

Wilson Bull., 106(3), 1994, pp. 421–430

IDENTIFYING SEX AND AGE OF AKIAPOLAAU

THANE K. PRATT, STEVEN G. FANCY, CALVIN K. HARADA, GERALD D. LINDSEY, AND JAMES D. JACOBI

ABSTRACT.—Methods for identifying the sex and age of the Akiapolaau (*Hemignathus munroi*), an endangered honeycreeper found only on the island of Hawaii, were developed by examination and measurement of 73 museum specimens and 24 live birds captured in mist nests. Akiapolaau probably undergo a single annual molt, with most birds molting between February and July. The mottled juvenal plumage is replaced by a first basic plumage characterized by yellowish-gray or yellowish-green underparts and often by retained wingbars. Male Akiapolaau may not attain adult plumage until their third molt. In adult females, only the throat and upper breast become yellow, whereas in adult males the superciliaries, cheeks, and entire underparts are yellow. Adult males have greater exposed culmen, gonys, wing chord, tail, and tarsus lengths than do females. Akiapolaau in first prebasic molt or older can be identified as to sex by culmen length, that of males being >23.4 mm. *Received 19 Aug. 1993, accepted 1 Dec. 1993.*

The Akiapolaau (*Hemignathus munroi*) is an endangered Hawaiian honeycreeper (Fringillidae: Drepanidinae) best known for its dual-action beak in which the mandible is a stout awl and the maxilla an elongated hook (Frontispiece). The species is distributed patchily through montane mesic and dry forest on the island of Hawaii, where Scott et al. (1986) estimated 1500 birds in low population density. This study describes the plumage sequence and morphometric and plumage characters for identifying the sex and age of Akiapolaau, based on museum skins and on live birds captured in mist nets. Previous descriptions of plumage and measurements from museum specimens are brief and incomplete (Wilson and Evans 1890–1899, Rothschild 1893–1900, Henshaw 1902, Amadon 1950), and recently published illustrations only show adult males with accuracy.

National Biological Survey, Hawaii Field Station, P.O. Box 44, Hawaii National Park, Hawaii 96718.

METHODS

We recorded plumage characteristics and external measurements for 73 Akiapolaau skins at the Bernice P. Bishop Museum (BPBM), Honolulu, Hawaii, and the National Museum of Natural History (NMNH) in Washington, D.C. Fifty-two of these specimens were collected by Henshaw (1902) between Hilo and Volcano from 1899 to 1902, a series never described in detail. Our sample included 64 specimens with sex indicated on the label. We assumed that birds were correctly sexed by examination of their gonads during specimen preparation. T. Pratt measured BPBM specimens and Kanakaleonui birds (see below); Michelle Reynolds, trained by Pratt, measured NMNH specimens. An additional 38 captures of Akiapolaau were measured, scored for molt, banded, and released where captured at Kulani Correctional Facility (C. Atkinson and R. Dusek, unpubl. data) or at Puu Laau and Kanakaleonui by various individuals (Fig. 1). Our analysis of timing of molt also included data for 57 captures of Akiapolaau at Keauhou Ranch (C. J. Ralph, unpubl. data).

We scored individual primaries, secondaries, and rectrices as missing, in sheath, or fully grown. All remaining feathers were considered body feathers and scored as (0) no molt, (1) 1–5 feathers in sheath, or (2) >5 feathers in sheath. Comparative wear on wing feathers of molting birds helped in determining which feathers were new or old. We considered birds to be in annual molt if more than five body feathers were in sheath or if primary and secondary feathers were molting symmetrically. We omitted juveniles from molt analysis because they do not undergo wing or tail molt.

For each specimen, we recorded the presence or absence of mottling on the head, throat, and upper neck, mottling being feathers tipped with darker gray in contrast to basal yellowish grey. We recorded presence or absence of wingbars (paler tips on greater and sometimes middle wing coverts). A ventral color score was assigned for each bird as follows: (1) all gray; (2) all yellowish gray or yellowish green; (3) chin and throat yellow, breast yellowish gray; (4) entirely yellow, cheeks green; or (5) entirely yellow, cheeks yellow. We coded the coloration of the superciliary as green or yellow and the coloration at the base of the mandible as pale or dark.

For each specimen, we also recorded standard measurements of wing cord (WING), exposed culmen (EXPCUL), tarso-metatarsus (TARSUS), and TAIL as described in Pyle et al. (1987) and Fancy et al. (1993). GONYS was measured from the tip of the mandible to the point where the rami join to form the gonys. We did not measure damaged structures.

After inspecting the frequency distribution of plumage and soft part scores and studying transitional plumages of birds in molt (see Results), we aged each specimen as juvenile, subadult, or adult. We conducted separate analyses for subadults and adults, using logistic regression and stepwise discriminant analyses to determine the best set of measurements for sexing Akiapolaau, and classified each museum specimen as to sex, using linear discriminant functions (SAS 1987). To produce unbiased error rates, we classified individuals by a jackknife procedure (i.e., each discriminant function was computed from the other observations in the data set, excluding the observation being classified; SAS 1987). The discriminant function was used to identify the sex of live birds that were independently sexed on the basis of plumage (adult males), breeding behavior, or presence of a brood patch (National Biological Survey, unpubl. data).

We compared WING and EXPCUL measurements for adult male Akiapolaau at four sites to test for geographic variation in measurements. For other sex and age classes, too few specimens were available. Measurements were recorded for museum specimens from Kaiwiki (N = 10, 500–800 m elevation), Olaa (N = 9, 500–800 m), and Kilauea (N = 6, 1200–2000 m) and for eight live males captured in mist nets at Kanakaleonui (2400–2700 m, Fig. 2).

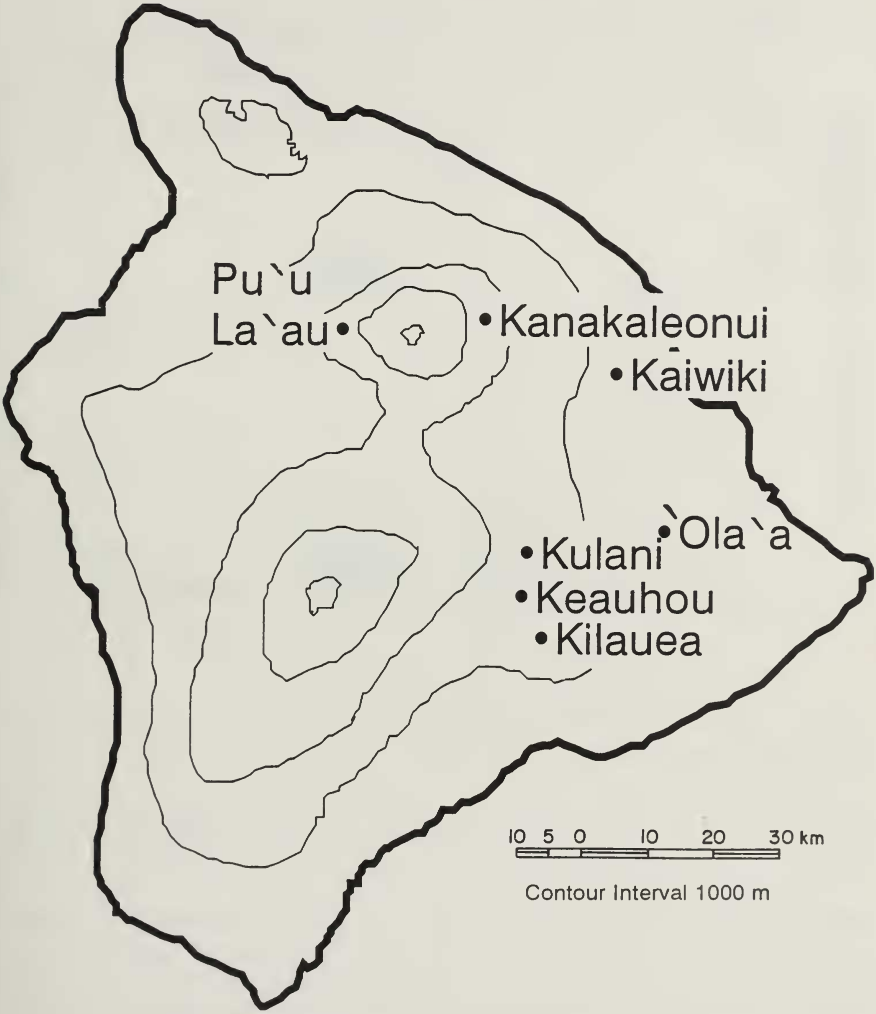

FIG. 1. Map of the island of Hawaii showing collecting and banding locations.

RESULTS

Seasonality of molt.—Though molting Akiapolaau have been captured throughout the year, our limited sample indicates a single broad peak in molting between February and July (Fig. 2). Absence of bimodal peaks suggests that the species molts once annually, as do other Drepanidinae (Amadon 1950, Baldwin 1953, Jeffrey et al. 1993).

Age identification.—The juvenal plumage of Akiapolaau, described

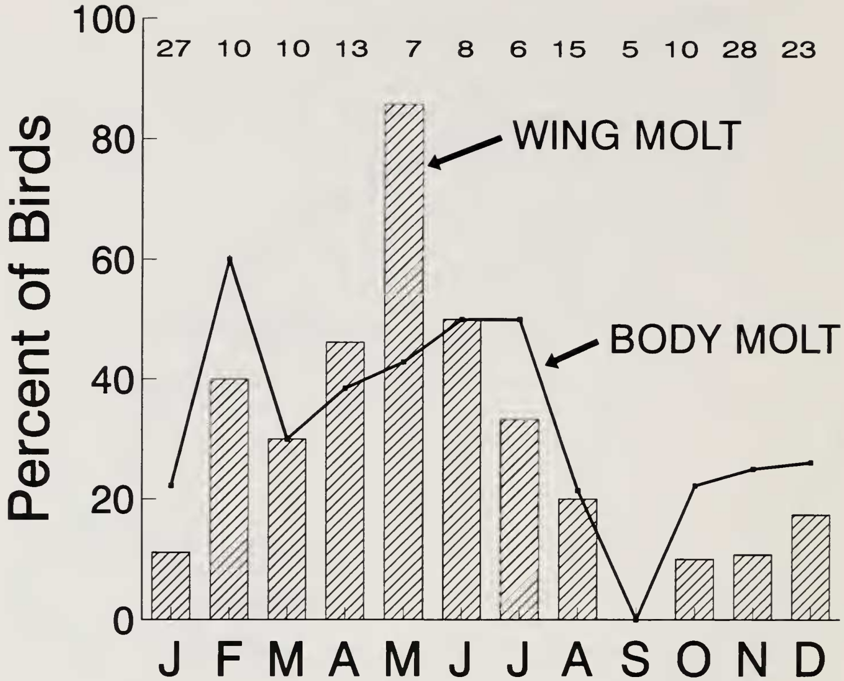

FIG. 2. Timing of wing (primary and secondary) and body molt in post-juvenile Akiapolaau. Sample sizes appear at top of the figure.

here for the first time, is characterized by a mottled appearance caused by dark-gray tips on the feathers of the head, throat, and upper breast. The plumage, overall, is yellowish-gray or green, with underparts paler (ventral score 2). Faint wingbars result from the thin, pale tips of greater and middle wing coverts. The mandible is yellowish at fledging but darkens to brown or black over a period of months, retaining pale coloration last at its base (Pratt, unpubl. data). Four specimens showed nearly complete juvenal plumage, and all were molting (body molt score 1 or 2 but no primary or secondary molt), suggesting that Akiapolaau begin their incomplete first prebasic molt within a few months of fledging.

The distinctive subadult plumage resembles juvenal plumage but lacks mottling. The underparts are pale yellowish gray or yellowish-green (ventral score 2), although a few females had grayish plumage with very little yellow suffusion (ventral score 1). Thirteen specimens had wingbars on the retained juvenal wing coverts (Fig. 3). Five specimens lacked wingbars that may have been too vague to be recognized, had worn off, or may have molted during the first prebasic molt. Presence of wingbars is

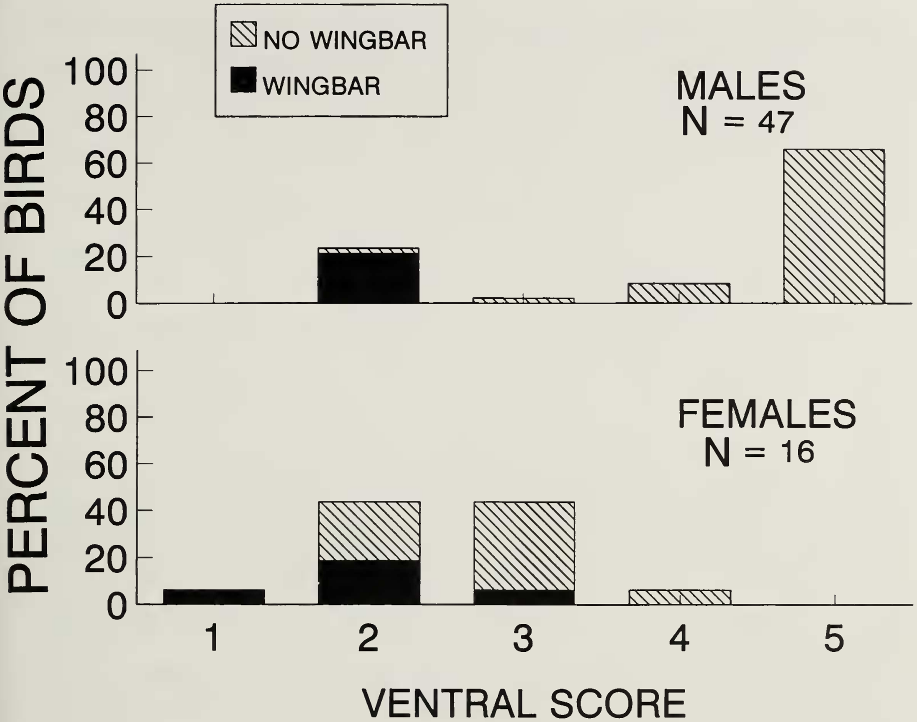

FIG. 3. Distribution of plumage scores for male and female Akiapolaau museum specimens. Ventral score is coded as (1) all gray, (2) all yellowish-gray or yellowish green, (3) chin and throat yellow, breast yellowish-gray, (4) entirely yellow, cheeks green, or (5) entirely yellow, cheeks yellow.

useful for identifying birds as juveniles or subadults, but absence of wingbars should not exclude assigning a bird to these age classes. The mandible of subadults is dark; the base of the mandible was pale on only one of 18 specimens. Adult plumage follows the complete second prebasic molt: of eight subadults in annual molt, six were molting primary or secondary feathers symmetrically.

Adult females have a yellow chin, throat and upper breast that contrasts with a pale yellowish-gray lower breast and belly (ventral score 3). This plumage lacks wingbars, although one adult female specimen retained wingbars (Fig. 3). One male specimen, without wingbars, possessed this plumage and may have been a subadult. We do not know if some females retain ventral score 2 for more than one year. One female had entirely yellow underparts and green cheeks (ventral score 4) and lacked wingbars and may have been in her second or later basic plumage.

Adult males have yellow superciliaries, cheeks, and underparts (ventral score 5), no wingbars, and black rather than dark gray lores. Four male specimens had yellow underparts and green cheeks (ventral score 4), no wingbars, and greenish superciliaries. One was molting from ventral score 2; another was molting into ventral score 5 (Fig. 3). Of these four birds, two with new flight feathers appeared to have undergone complete molt and may have been in their second or third basic plumage.

Recaptures and sightings of banded birds showed that the adult plumages for males and females did not change between molts. We captured one female in subadult plumage (ventral score 2) that when captured eight months later had molted into adult plumage (ventral score 3) and was tending a fledged chick. A captured female with gray plumage and a wingbar had an active brood patch (Lepson, pers. comm.), indicating that females in subadult plumage can breed.

We were unable to age birds reliably from measurements alone. Subadult and adult females differed only in wing chord length, which was shorter in subadults ($t = 2.14$, 14 df, $P = 0.051$). Subadult males had shorter WING ($t = 2.30$, 40 df, $P = 0.026$), EXPCUL ($t = 2.41$, 30 df, $P = 0.022$) and GONYS ($t = 2.70$, 37 df, $P = 0.011$) measurements than did adult males.

Sex identification.—Only adult male Akiapolaau can be sexed reliably by plumage characteristics, so we conducted separate analyses for subadult and adult Akiapolaau to develop criteria for sexing birds from measurements. EXPCUL was the only variable to enter the discriminant function for sexing subadult birds. We accurately sexed 17 of 18 (94%) subadults by identifying all birds with EXPCUL lengths ≥23.3 mm as males and those with shorter culmens as females. In separate *t*-tests, subadult males had longer wing, exposed culmen, gonys, and tarsus lengths than did subadult females (Table 1).

The discriminant function:

$$D = 1.318(\text{EXPCUL}) + 0.313(\text{WING}) - 55.689$$

correctly sexed 28 of 30 (93%) adult Akiapolaau, in which birds with a discriminant score of $D \geq 0$ are identified as males. Adult male Akiapolaau had longer wing, culmen, and gonys lengths than did adult females (Table 1).

We also computed a discriminant function after pooling data for subadult and adult Akiapolaau because of the difficulty in identifying the age of some postjuvenile birds. We accurately sexed 44 of 48 (92%) subadult and adult museum specimens by identifying all birds with EXPCUL ≥23.4 mm as males and those with smaller culmens as females. We also found that a cutoff EXPCUL length of 23.4 mm accurately sexed 37 of

TABLE 1

COMPARISON OF MEASUREMENTS (MM) FOR MALE AND FEMALE AKIAPOLAAU SPECIMENS BY AGE CLASS

	Females				Males					
	N	Mean	SE	Range	N	Mean	SE	Range	t[a]	P
Juvenile										
Wing chord					5	79.00	0.95	76.0–81.0		
Tail					5	41.80	0.86	39.0–44.0		
Exposed culmen					4	24.57	1.11	22.5–27.7		
Gonys					5	13.50	0.45	12.3–14.7		
Tarsus					5	24.94	0.26	24.3–25.5		
Subadults										
Wing	10	77.30	0.42	75.0–80.0	10	79.70	0.73	77.0–85.0	2.8	0.011
Tail	10	41.40	0.43	39.0–43.0	10	43.20	0.90	40.0–48.0	1.8	0.095
Exposed culmen	10	21.45	0.34	19.6–23.1	8	24.96	0.47	23.3–26.9	6.2	0.000
Gonys	10	11.93	0.18	10.9–12.6	10	13.10	0.25	12.2–14.7	3.8	0.001
Tarsus	9	24.36	0.22	23.0–25.1	9	25.10	0.26	23.8–26.1	2.2	0.044
Adults										
Wing	6	78.67	0.42	77.0–80.0	32	81.56	0.39	77.0–88.0	3.1	0.004
Tail	6	42.50	0.56	40.0–44.0	32	43.88	0.36	40.0–49.0	1.6	0.119
Exposed culmen	6	21.97	0.80	19.4–24.8	24	26.61	0.36	22.6–30.8	5.6	0.000
Gonys	5	11.88	0.45	11.0–13.4	29	13.87	0.14	12.6–15.6	5.1	0.000
Tarsus	6	24.03	0.42	22.7–25.3	31	25.06	0.17	23.4–28.0	2.5	0.019

[a] t-test for difference in measurements between sexes.

38 (97%) live birds (including recaptures) from an independent sample of 17 adult males and six subadult and adult females. One female from Kanakaleonui had an EXPCUL of 23.9 mm.

Geographic variation in measurements.—Skin specimens from Kai-

TABLE 2

WING AND EXPOSED CULMEN MEASUREMENTS (MM) FOR ADULT MALE AKIAPOLAAU AT FOUR SITES

		Wing			Exposed culmen		
Site[a]	Elevation (m)	N	Mean	SE	N	Mean	SE
Kaiwiki	500–800	10	81.4	0.60 (A)[b]	8	26.6	0.37
Olaa	500–800	9	81.7	1.05	6	28.2	0.64 (A)
Kilauea	1200–2000	6	82.2	0.40	5	25.3	0.77 (A)
Kanakaleonui	2400–2700	8	84.4	0.65 (A)	8	27.5	0.55

[a] Birds from Kanakaleonui were measured alive; all others were museum skins.

[b] Means with the same letter are significantly different ($P < 0.05$, Tukey's studentized range test, SAS 1987).

wiki had shorter wings than live adult males at Kanakaleonui (Table 2). Exposed culmen lengths of Kaiwiki and Kanakaleonui males did not differ significantly from culmens of males from other sites, but skins of males from Kilauea had significantly shorter culmens than those from Olaa (Table 2).

DISCUSSION

Akiapolaau can breed and molt at any time of year (Amadon 1950; Banko and Williams 1993; Ralph and Fancy 1994; this study) and so cannot be aged by the calendar year method of the USFWS Bird Banding Laboratory (Canadian Wildlife Service 1984). Phenology of breeding is not well understood. Banko and Williams (1993) summarized data for five Akiapolaau nests discovered in January (2 nests), February, July, and October. Lepson (pers. comm.) reported three active nests in March, May, and June. Ralph and Fancy (1994) captured males with enlarged cloacal protuberances throughout the year and captured females with brood patches in January, February, May, June, August, and October. Atkinson and Dusek (unpubl. data) captured females with brood patches in March and June. These few data suggest that most Akiapolaau nest from January through August.

In passerines, annual molt generally follows breeding (Newton 1972, King 1974, Pyle et al. 1987). Amadon (1950) reported molt in Akiapolaau from June through September. We found that although most Akiapolaau molt in spring and summer, birds in prebasic molt can be found at any time of year. Other native forest birds in Hawaii breed during spring and summer and molt in late summer and fall, with very few birds molting at other times (Amadon 1950; Fancy et al. 1993; Jeffrey et al. 1993; Ralph and Fancy 1994). Akiapolaau appear to be unique among Hawaiian forest birds in that seasonality in breeding and molting overlap and that in any month a larger proportion of Akiapolaau are molting. Perhaps individual Akiapolaau molt over a relatively long period. Alternatively, weak seasonality in breeding by Akiapolaau may result in weak synchrony in molt within the population. Further, Akiapolaau parents, unlike other drepanidines, provide care for juveniles for many months (Lepson, pers. comm.; Pratt, unpubl. data), which may prevent renesting but permit the early onset of molt. If so, the long period of molt may be due to renesting by some birds that postponed molt until young were successfully fledged from subsequent nests.

The mottled juvenal plumage of Akiapolaau may be homologous to the dark-tipped juvenal plumage of other drepanidines (e.g., Laysan and Nihoa finches [*Telespyza cantans* and *T. ultima*], Apapane [*Himatione sanguinea*], and Iiwi [*Vestiaria coccinea*]). Also in common with many drepanidines, Akiapolaau begin their first prebasic molt within a few months of fledging and often retain the pale-tipped juvenal wingbars in the first basic plumage.

Akiapolaau show variation in first basic plumage for both sexes and possibly for later female plumages. Molt in some specimens suggests that males may undergo more than two prebasic molts to attain adult plumage, as in another drepanidine, the Akepa (*Loxops coccineus*; Freed et al. 1987; J. Lepson, pers. comm.). Additional field studies are needed to better understand variation in plumages and molt sequence of Akiapolaau.

Identifying the sex of Akiapolaau in juvenal plumage is difficult because of uncertainty about the month of hatching and because bill length, which we found to be the most useful means of sexing older birds from measurements, increases during the first year. We found no difference in bill measurements between subadult and adult females, indicating either that bill growth stops during the first year or that we misidentified some adults as subadults. Or perhaps in a larger sample size, we could have detected a difference. Adult males had longer EXPCUL and GONYS than did subadult males, however, indicating that in males the bill continues to grow into the birds' second year. Perhaps the foraging niche of males changes as they mature or bill length may serve as a secondary sexual character.

Akiapolaau measurements showed little geographic differentiation. The four sites sampled spanned 2100 m in elevation and included extremely wet lowland rainforest (Kaiwiki and Olaa), montane mesic forest (Kilauea), and subalpine xeric woodland (Kanakaleonui). Akiapolaau, being territorial and sedentary, would not be expected to move among these sites. WING averaged about 3% larger for birds from Kanakaleonui, the site of greatest elevation. This size difference may be an artifact of comparing measurements from live birds with those from study skins, which shrink in preparation (Herremans 1985). If not, then Akiapolaau support the trend in size increase with altitude for some nonmigratory tropical bird species (Diamond 1972). The three males that were incorrectly sexed by the discriminant function because of small EXPCUL were from Kilauea. These males had larger EXPCUL than females from that site. We recommend that persons using measurements to sex Akiapolaau be wary of potential regional differences. Nevertheless, sexes from a single site should be easily distinguished by measurements, and if necessary, an adjusted cutoff point can be established for a local population.

ACKNOWLEDGMENTS

We thank C. Kishinami, R. Pyle, and A. Allison, for access to collections at the B. P. Bishop Museum, S. Olson for access to the U.S. Museum of Natural History, M. Reynolds for measuring the USNM specimens, and P. Chang for field assistance. We also thank C. Atkinson, R. Dusek, and C. J. Ralph, for allowing us to incorporate their unpublished data on this rare species, and H. D. Pratt for permission to publish a plate of his painting. J. Hatfield, J. Lepson, H. D. Pratt, and S. Rohwer provided instructive review of early drafts of this paper. The study was supported in part by the Bernice P. Bishop Museum, Hawaii Conservation Biology Initiative, and Hawaii Natural Area Reserve System.

LITERATURE CITED

AMADON, D. 1950. The Hawaiian honeycreepers (Aves, Drepaniidae). Bull. Am. Mus. Nat. Hist. 95:157–262.

BALDWIN, P. H. 1953. Annual cycle, environment and evolution in the Hawaiian honey-creepers (Aves: Drepaniidae). Univ. Cal. Press, Los Angeles, California.

BANKO, P. C. AND J. WILLIAMS. 1993. The egg, nest, and some aspects of nesting behavior of Akiapolaau (Drepanidinae: *Hemignathus munroi*). Wilson Bull. 105:427–435.

CANADIAN WILDLIFE SERVICE. 1984. North American bird banding. Vol. I. Can. Wildl. Serv., Ottawa, Ontario, Canada.

DIAMOND, J. M. 1972. Avifauna of the eastern highlands of New Guinea. Publ. Nuttall Ornithol. Club 12.

FANCY, S. G., T. K. PRATT, G. D. LINDSEY, C. K. HARADA, A. H. PARENT, JR., AND J. D. JACOBI. 1993. Identifying sex and age of Apapane and Iiwi on Hawaii. J. Field Ornithol. 64:262–269.

FREED, L. A., S. CONANT, AND R. C. FLEISCHER. 1987. Evolutionary ecology and radiation of Hawaiian passerine birds. Trends Ecol. Evol. 2:196–203.

HENSHAW, H. W. 1902. Birds of the Hawaiian Islands, being a complete list of the birds of the Hawaiian possessions with notes on their habits. T. G. Thrum, Honolulu, Hawaii.

HERREMANS, M. 1985. Post-mortem changes in morphology and its relevance to biometrical studies. Bull. Br. Ornithol. Club 105:89–91.

JEFFREY, J. J., S. G. FANCY, G. D. LINDSEY, P. C. BANKO, T. K. PRATT, AND J. D. JACOBI. 1993. Sex and age identification of Palila. J. Field Ornithol. 64:490–499.

KING, J. R. 1974. Seasonal allocation of time and energy resources in birds. Pp. 4–85, *in* Avian energetics (R. A. Paynter, Jr., ed.). Publ. Nuttall Ornithol. Club 15.

NEWTON, I. 1972. Finches. Collins, London.

PYLE, P., S. N. G. HOWELL, R. P. YUNICK, AND D. F. DESANTE. 1987. Identification guide to North American passerines. Slate Creek Press, Bolinas, California.

RALPH, C. J. AND S. G. FANCY. 1994. Timing of breeding and molting in six species of Hawaiian honeycreepers. Condor 96:151–161.

ROTHSCHILD, W. 1893–1900. The avifauna of Laysan and the neighboring islands. 3 vol. R. H. Porter, London.

SAS. 1987. SAS/STAT guide for personal computers. Version 6 edition. SAS Institute, Inc., Cary, North Carolina.

SCOTT, J. M., S. MOUNTAINSPRING, F. L. RAMSEY, AND C. B. KEPLER. 1986. Forest bird communities of the Hawaiian Islands: their dynamics, ecology and conservation. Stud. Avian Biol. 9:1–431.

WILSON, S. B. AND A. H. EVANS. 1890–1899. *Aves Hawaiienses*: the birds of the Sandwich Islands. R. H. Porter, London, England.